HRRR v3 Enhancements status

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1. Introduction

This report summarizes the status of work toward HRRRv3 and includes selected results of ongoing retrospective testing. Associated RAPv4 development work is also included, as many of the changes (especially physics changes) are common to both systems. Work to date has been completed with retrospective testing only. Transfer of updates to the GSD real-time parallel RAP/HRRR system has been delayed until implementation of the RAPv3/HRRRv2 at NCEP. Key areas for improvement are further enhancements to the physics modules (especially the MYNN planetary boundary layer scheme and Smirnova land surface model), increasing the ensemble weighting in the hybrid data assimilation, and use of new observation types in the assimilation.

Table 1 provides a list of planned / possible changes. Items in blue or red are likely upgrades, with red items directly addressed in this report. Items in green are upgrades that are possible in the next RAP/HRRR version.

RAPv4/HRRRv3 ESRL Development 39/36 hr Runs

	Model	Data Assimilation
RAPv4 (13 km)	WRF-ARW v3.8+ incl. physics changes Physics changes: Thompson microphysics – improved upper-level clouds MYNN PBL update – better sub-grid clouds, meso env LSM update – 15" MODIS data – better lower boundary VIIRS-based real-time greenness vegetation fraction Numerics changes: Improved terrain (cell avg) – better winds /turbulence Hybrid vertical coordinate from NCAR	Merge with latest GSI trunk New Observations for assimilation: NCEP new VAD wind retrievals, satellite ATMS/CrIS Add AMVs over land and TAMDAR GOES-R lightning mapper – convection proxy Assimilation Methods: Revised PBL pseudo-obs – reduce RH bias More ensemble weight in hybrid DA (0.9/0.1) METAR and GOES cloud building now consistent Aircraft temperature bias correction
Likely update Likely update, discuss in report Possible inclusion		
HRRRv3 (3 km)	WRF-ARW v3.8+ incl. physics changes Physics changes: Thompson microphysics – improved upper-level clouds MYNN PBL update – better sub-grid clouds, meso env LSM update – 15" MODIS data – better lower boundary VIIRS-based real-time greenness vegetation fraction Add smoke with VIIRS fire radiative power? Numerics changes: Hybrid vertical coordinate from NCAR	New Observations for assimilation: GOES cloud-top cooling rates – convection proxy Add new VAD wind, AMVs over land and TAMDAR GOES-R lightning mapper – convection proxy Radar radial velocity at 3km – better convection METAR and GOES cloud building now consistent DA Methods: More ens weight in hybrid DA (.9/.1) – better winds Full atmospheric cycling – better 0-4 hr convection Variational/hybrid cloud analysis – better C/V

Table 1. List of changes being evaluated for the RAPv4 / HRRRv3.

2. Model physics changes

Key focus areas for the physics development continue to be the MYNN (Mellor–Yamada–Nakanishi–Niino) planetary boundary layer scheme to better account for vertical transport and subgrid scale cloudiness (coupled with the radiation scheme). A significant enhancement is the inclusion of an eddy-diffusion mass-flux (EDMF) component in the MYNN, which provides a better representation of the boundary layer structure, especially in the convectively unstable environments. The MYNN has traditionally been cast as a local-closure eddy diffusivity scheme. A known deficiency to this approach occurs in convective boundary layers, where large overturning eddies accomplish so-called "nonlocal" transport of heat, water vapor, and momentum. The mass-flux addition makes the MYNN capable of running as an EDMF scheme. This will improve the representation of convective boundary layers by parameterizing updrafts as a nonlocal mass-flux process, instead of simple diffusion. If those updrafts reach their LCL (i.e., forming a shallow-cumulus cloud), the MYNN-EDMF scheme will produce a cloud fraction (coupled to radiation). Expected benefits from running the MYNN in EDMF mode include further reduction in the daytime 2-m warm bias, better vertical temperature profiles in the PBL (i.e., no unrealistically deep superadiabatic layers, and hopefully a better retention of capping inversions), and likely better timing of deep-convective initiation (through better preconditioning of the PBL)

This change has been tested in a retrospective environment from July 2014 which isolates this change, but does not assess its interaction with other planned enhancements. Also, we are continuing to make smaller adjustments to this and other schemes, so the results shown do not represent a completely finalized form of the scheme as it will be included in the RAPv4/HRRRv3. Finally it should be noted that while only HRRR results are shown, these enhancements have been included in both the RAP and HRRR and the HRRR changes reflect impact from both the HRRR and the parent RAP.

Fig. 1 shows average diurnal cycle of the surface temperature and dewpoint RMS and bias errors for the retrospective period. The top plots show that both the temperature and dewpoint RMS errors are similar or slightly better at all times of the day for proto-HRRRv3. Temperature biases are also reduced at all times of the day, while the high overnight dew point bias is a bit worse. Subsequent work has been focused on improving that result.

Fig. 2 shows the average CSI and bias scores for two different thresholds (20 dBz and 35 dBz). CSI scores are slightly lower for the HRRR with the MYNN enhancement, but bias scores are reduced to a value closer to 1, indicating a reduction in the overprediction of convection. Note that the scales for the y-axes on the bias plots are zoomed in and that the values are multiplied by 100, so that 120 means a bias of 1.2 (larger than the desired value of 1.0).

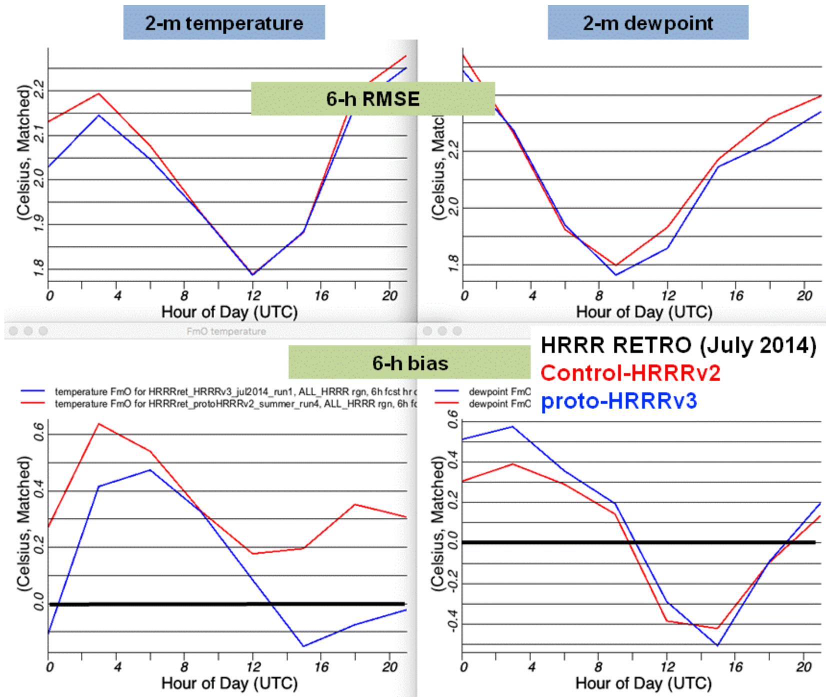

Fig 1. Comparison for surface temperature and dewpoint RMSE and bias errors of proto-HRRRv3 (blue -- with enhancements to MYNN PBL scheme) vs. GSD HRRRv2 (red).

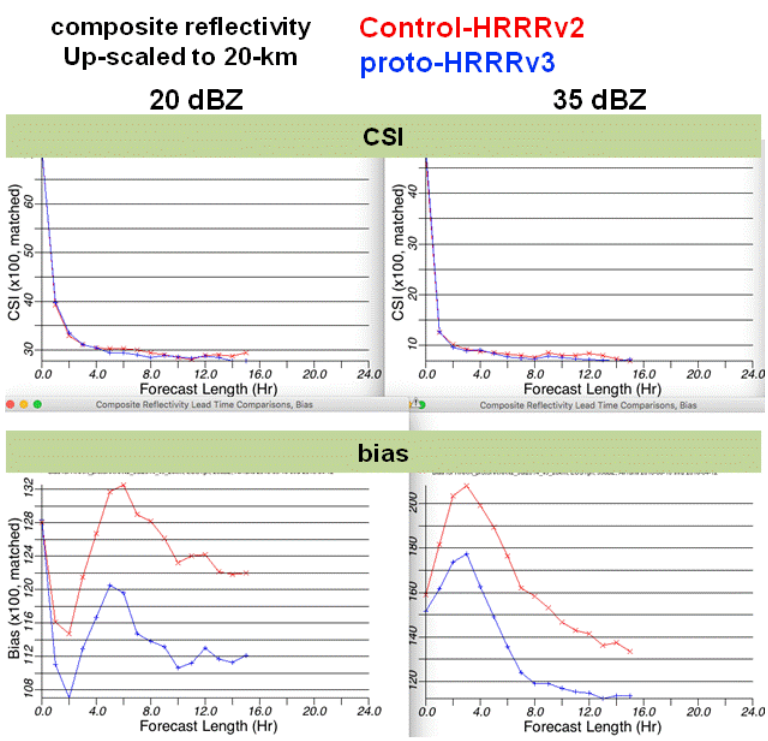

Fig 2. Comparison of critical success index (CSI) and frequency bias for two different values of reflectivity for proto-HRRRv3 (blue -- with enhancements to MYNN PBL scheme) vs. GSD HRRRv2 (red).

Additional changes include upgrades to the Smirnova land Surface model (LSM), including:

1. Testing of real-time VIIRS (Visible Infrared Imaging Radiometer Suite) green vegetation Fraction (GVF) data in cold-start RAP. The real-time data is ftp-ed from NASA-SPoRT. Jonathan Case from NASA SPoRT developed the pre-processing of the data for easy use with WRF-based models.

2 . Modification to RUC LSM's canopy evaporation, following Lawrence et al. 2007. This modification reduces the interception of precipitation by the canopy, and consequently reduces contribution of canopy evaporation into total evapotranspiration (more realistic). This modification was tested in the retro run for July 2014.

These tests have been completed with the RAP, but enhancements will be incorporated into both RAP and HRRR.

The VIIRS GVF data have the potential to improve upon the climatological MODIS greenness data. Qualitative examination of the data files indicates that the GVF data reflect well the dryness in the SW US and also the smaller greenness in Alaska (Fig. 3). The areas of reduced greenness exhibit higher 2-m temperature and lower 2-m dew point values for RAP forecasts as can be seen in Fig. 4.

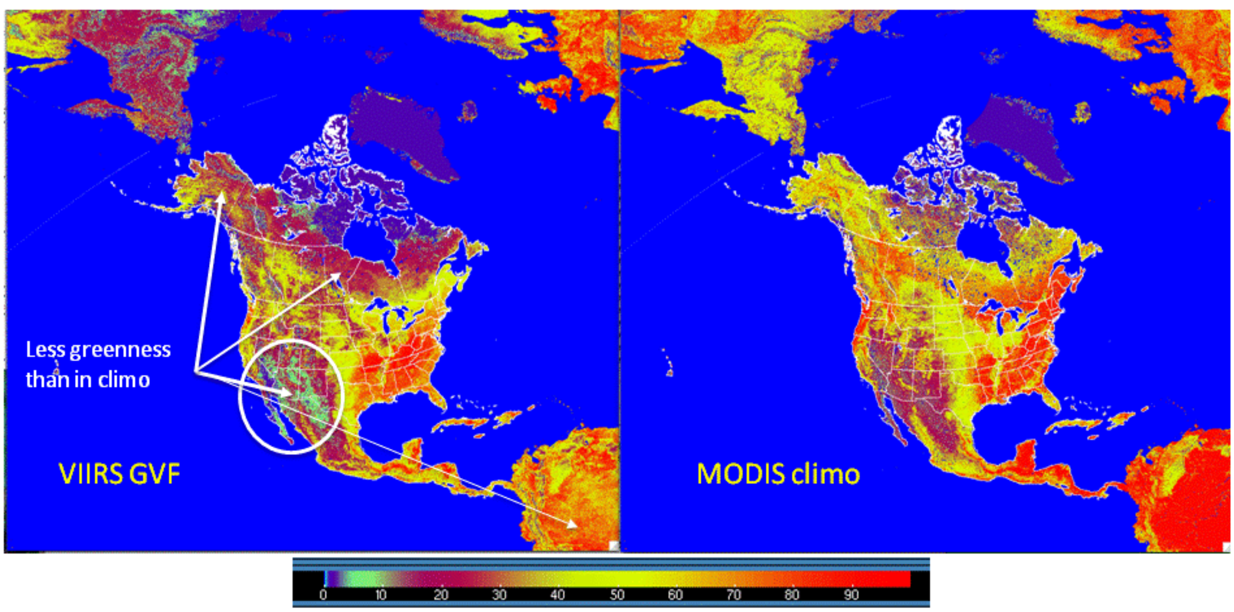

Fig 3. Comparison of VIIRS GVF versus MODIS vegetation fraction climate for 00z 20 June 2016. Specific areas of lower VIIRS greenness are indicated.

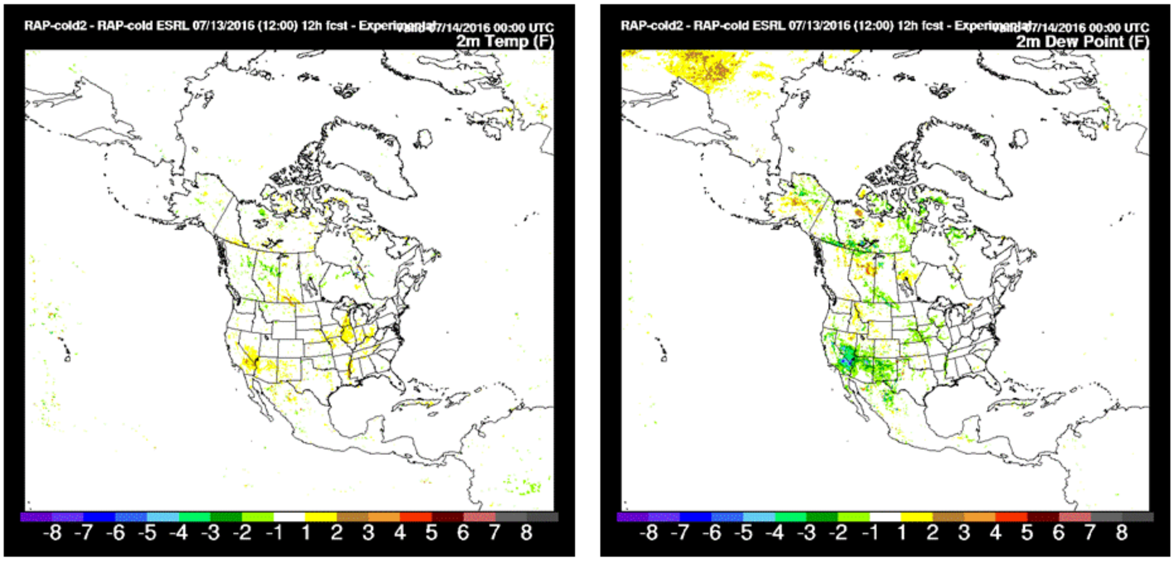

Fig 4. Differences in 12-h RAP forecasts of 2-m temperature (left) and 2-m dew point (right) for 00z 20 June 2016 for runs with the new VIIRS GVF minus the old MODIS greenness . Higher values for the VIIRS appear as yellow to brown and lower values for VIIRS appear as green to blue.

Testing for the canopy evaporation is ongoing. Results so far indicate a small improvement in the bias for both temperature and dew point as shown in Fig. 5, results from a July 2014 retrospective test case.

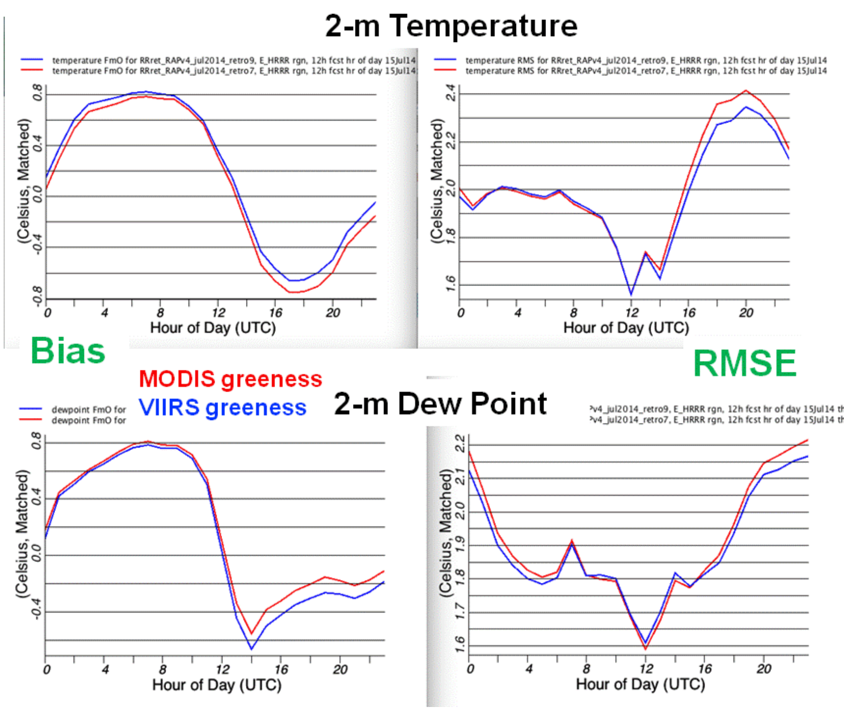

Fig 5. Diurnal cycle of RMSE and bias for 2-m temperature and 2-m dew point for retrospective case with VIIRS greenness (blue curves) vs. MODIS greenness (red curves).

Testing is also ongoing of the new alternate WRF-ARW vertical coordinate, which transitions for normalized pressure to pressure at upper levels. Initial tests with a transition at sigma = 0.2 (~200 hPa) indicate less terrain related noise (as desired) at upper-levels. There is some noise remaining at the top model level and work with NCAR scientists is ongoing to resolve this.

3. Data assimilation changes

Data assimilation upgrades include further increasing the weight of the global ensemble in the hybrid assimilation from 0.75 likely to 0.9, adding assimilation of additional observations (ATMS and CrIS satellite radiance data in the RAP; radial velocity, GOES cloud-top cooling rate data in the HRRR), and a number of smaller changes (including adjustment to the specification of pseudo-observations in the surface observation assimilation scheme). Prior to adding these changes, the RAP/HRRR version of GSI was updated to be consistent with the latest GSI repository trunk version. A retrospective for a period from 9-13 Aug. 2014 was then completed to verify the performance after this upgrade. 6-h forecast results from this retro, which also includes a minor adjustments to the cloud building (restrict METAR building to lowest 1200 m) are shown in Fig. 6. In general, RMS errors are slightly improved for wind, temperature, and relative humidity in the run with the new code sync and modification to the METAR cloud building.

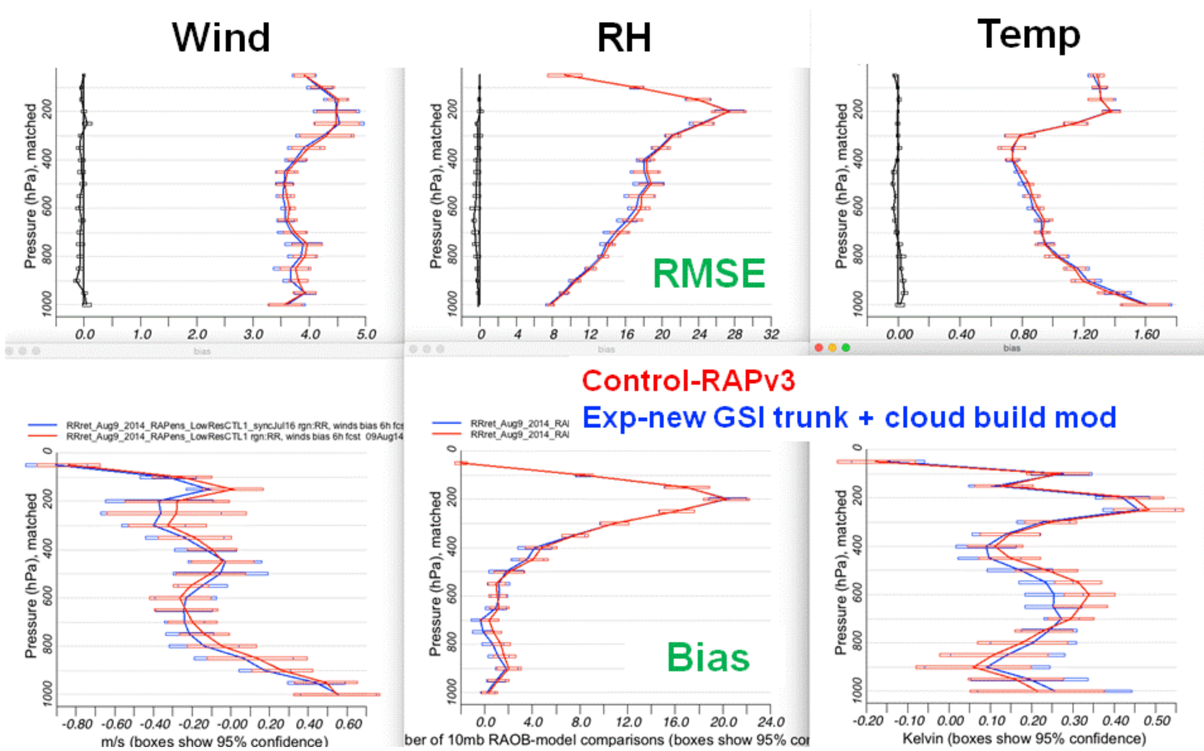

Fig 6. Average RMS errors and bias errors for radiosonde verification of RAP retrospective runs from 9-13 Aug. 2014. Comparison shows is of the RAPv3 control (red) vs. a prototype RAPv4 version with an upgrade to a newer trunk version of the GSI and a modification to remove cloud building above 1200 m.

A preliminary test of increasing the weight in the GSI hybrid analysis of the global ensemble to 0.85 indicated near neutral to slight forecast improvement (results not shown).

Development work on the challenging variational cloud analysis task has been progressing well, with the following components in place within GSI: routines to calculate total cloud condensate (cloud water + cloud ice) innovations for METAR and satellite cloud top pressure observations, control variable and variational solver for total cloud condensate, and partitioning of total cloud condensate increment between cloud water and cloud ice. Testing of the procedure indicates it is generally working as expected, though an issue related to the density of observations is still under investigation.

Other planned data assimilation changes include addition of direct readout ATMS (Advanced Technology Microwave Sounder) and CrIS (Cross-track Infrared Sounder) satellite radiance data in the RAP, and assimilation of the GOES cloud-top-cooling rate (CTCR) data and radar radial velocity data in the HRRR. Preliminary tests with ATMS data indicated only small positive impacts, but work is ongoing to improve the bias correction. We are analyzing the CrIS data to determine optimal channel selection (removal of channels that sense predominately in the stratosphere and would be aliased in the RAP due to the relatively low RAP model top). The GOES CTCR data hve been tested in retrospective mode, with a small positive impact for the early stages of some convective events. Very preliminary testing of the radial velocity data in a two-pass GSI application has yielded only neutral results, but we expect improvement once the assimilation length scales are optimized.

4. Summary

This report has provided an update on selected details of the ongoing work toward the RAPv4 / HRRRv3. Delays in the NCEP implementation of the RAPv3 / HRRRv2 coupled with the need to maintain a matched parallel real-time RAP/HRRR system at GSD until the implementation has lead to delays in the work toward RAPv4 / HRRRv3. In particular, we have been unable to move various components into a parallel real-time RAP/HRRR system to test the interaction and gauge their performance of a long period of day-today weather. We have continued to test components for a variety of retrospective cases, which has allowed us to continue to make progress toward the RAPv4 / HRRRv3. We had hoped to potentially start up a real-time cycle on separate computer hardware in early August (in time to provide some grids for the Aviation Weather Testbed program), but we were not able to accomplish this. The most vetted physics enhancements (MYNN upgrades including the Chaboureau and Bechtold sub-grid cloud scheme that was not discussed here, LSM upgrades) and data assimilation enhancements will be moved into the GSD real-time RAP/HRRR as soon as the implementation is completed (currently scheduled for Tues. 23 August). Active testing will continue through the fall with an anticipated finalization of codes for RAPv4 / HRRRv3 early in 2017.